N94-15605

Development of Shanghai Satellite Laser Ranging Station

F. M. Yang, D. T. Tan, C. K. Xiao, W. Z. Chen, J. H. Zhang
Z. P. Zhang, W. H. Lu, Z. Q. Hu, W. F. Tang and J. P. Chen

Shanghai Observatory, Academia Sinica
80 Nandan Road, Shanghai 200030, China
Telex: 33164 SHAO CN
Fax: 86-21-4384618
Phone: 86-21-4386191

1. Improvement of the System Hardwares

1.1 Computer control subsystem

An IBM/286 computer control system was set up during August 1989 to March 1990. After three months, the realtime display of range residuals (O-C) on the computer screen was completed. Since then, only one operator has been needed for the routine observation. The operator can control the whole ranging system by using the computer keyboard during the observation and can watch the image of the satellite while illuminated by the sunlight on the monitor of a SIT TV camera side by side. The system automation and reliability has been greatly improved.

1.2 Laser Subsystem

The Nd:YAG mode-locked laser, which was made by the Shanghai Institute of Optics and Fine Mechanics and installed at the station in 1986, contains an oscillator and three single-pass-amplifiers and can usually produce 50 mj (green) and 180 psec width.

Many work have been done in order to improve the stability on both the laser beam direction and the output energy. A new chiller was installed in November 1991. The repetition rate is 1-2 Hz for Lageos and Etalon ranging, and 2-4 Hz for low orbit satellites ranging. The divergence of the laser is about 0.4 mrad. So, the optimum beam divergence from the transmitting telescope which has a magnification of 6 is about 13 arcseconds. That is good for Etalon satellites ranging. The divergence can be adjusted up to 3 arcminutes for the low orbit satellites ranging.

1.3 Receiver

The ordinary PMT (Type GDB49A, China-made) has been adopted from the set up of the system in 1983 to May 7, 1992 when a single photon avalanche diode (SPAD) receiver made by the Czech Technical University has been installed. The voltage for the diode is about 30 V and the break down voltage is about 27.5 V. The field of view of the new receiver is about 45 arcsec. The noise rate of the SPAD working at above condition is 200-300 KHz even in the nighttime.

A 0.15 nm narrow band filter in a theomostat has been tested in November-December 1991 and has been shown with good performance.

2. Upgrading of the Softwares

2.1 The prediction of the satellite range

The IRV ephemerides for Lageos and Etalon-1,2 from Texas/CSR, the IRV for ERS-1 from DGFI and the SAO elements (Kepler orbital elements) for Ajisai and Starlette From NASA/GLTN have been used for the routine observations. The range residuals of prediction for Lageos is about 5-10 meters by introducing the corrections of the Time-bias (monitored by ourselves) and UT1 prediction from USNO Bulletin.

2.2 An error model of the tracking mount for reducing the systematic errors has been built. After the star calibration, the pointing accuracy of the mount is about 5 arcsec.

2.3 On-site normal point generation

The program of the on-site normal point generation was finished in March 1992. Since then, these normal points of the routine observation have been transmitted to the data centers.

2.4 New pre-processing program

A M-estimate program for better noise rejection purpose has been developed in stead of the least-squares estimate [Tan Detong, et al, this proceedings]. The new program has a stronger capability to deal with those passes which contain more noises and especially with the "end effect" of the fit curve, it means the noises at the both ends of the observation curve can be easily edited.

3. The Observation Status

3.1 The summary of the observations

After the above efforts, especially on the system automation, the performance of the laser ranging has been greatly improved, and the quantity of the observation passes has been dramatically improved since July 1990, even in Shanghai--the poor whether area. The observation staff works pretty hard, 14-16 hours per day and 7 days per week, if the whether permitting.

* The maximum number of passes obtained in one month 98 passes (Jan. 1992)
* The maximum number of passes obtained in one night 12 passes
* The maximum number of points obtained in one pass 4265(Eta-2) 2865(Lageos)
* The estimate of range precision (single shot,rms) from 1988---up to May 7,1992 is about 4-5 cm.

* Fig.1 & 2 are the O-C residuals of Etalon-2 and Lageos passes.

Summary of SLR Observations at Shanghai (7837)

Year / Satel.	1988		1989		1990		1991		1992*	
	pass,	point	pass,	point	pass,	point	pass,	point	pass,	point
Lageos	37,	2625	33,	2555	162,	73782	137,	35071	89,	22409
Ajisai	41,	4033	74,	4323	158,	30594	134,	33183	48,	12637
Starlette	4,	142	12,	332	44,	6135	59,	9122	35,	2946
Etalon-1					38,	22222	21,	3888	13,	1579
Etalon-2					35,	10402	26,	7430	22,	1737
ERS-1							25,	2088	24,	3074
TOTAL	82,	6800	119,	7210	437,	143135	402,	90782	231,	44382

* up to May 9, 1992

3.2 **Multi-satellite tracking capability**
The typical time interval for the system to transfer from one satellite to another is about one minute, including the telescope moves back to the zero point and then travel to the prediction position of another satellite. The shortest time interval from the last return of Lageos pass to the first return of Etalon pass was only 126 seconds.

4. Preliminary Daylight Tracking Capability

After having the above-mentioned improvements, the daylight tracking to Lageos had been tested during November and December, 1991. The first returns in the daylight was obtained on December 20, local time 16:47 P.M. (Fig. 3)
The aperture of the receiving telescope is 600 mm, and the field of view of the receiver is 60 arcsec, 0.15 nm (FWHM) filter, PMT Type GDB-49A, the noise rate of the sky background was about 800 KHz.

5. Testing the New Type Laser

In April and May, 1992, a new Nd:YAG laser with an unstable resonator hybrided by nonlinear ring interferometer has been tested for satellite ranging at Shanghai station. Another paper [Yang Xiangchun et al, this Proceedings] introduces the technique for simultaneously compressing of

the passive mode-locked pulsewidth and pulse train. For SLR application, one amplifier and one frequency doubler were added to the oscillator. Without the single pulse selector, the output of the laser system was in pulse train containing only 1-2 giant pulses, and the total energy of the pulse train is about 18 mj (green), 10 psec width, 0.4 mrad beam divergence, 2-4 Hz repetition rate. During May 8-9, the new laser system and the SPAD receiver has been successfully used for Lageos and Etalon-1 ranging. The 2 cm range accuracy has been achieved in both satellite and ground target ranging. (Fig. 4 & 5)

6. Future Plans

6.1 Routine daylight ranging to Lageos and other low orbit satellites.

6.2 Single shot range accuracy will be improved to better than 2cm for routine operation.

6.3 **Development of the millimeter level accuracy SLR system**
A cooperative plan between Shanghai Observatory and Xi'an Institute of Optics and Precision Mechanics has been set up to develop a mm- level SLR system based on a circular-scan streak tube. A prototype tube has been made by Xi'an Institute in March 1991. The main characteristics of the tube is as follows:

* Photocathode:	Type S-20, Sensitivity	67 μA / lm
	Spectrum response	200-850 nm
	Effective area	12 mm
* Sensitivity of deflection		10 cm / KV
* Double MCP internal intensifiers		
* Gain		1×10^6
* Spatial resolution		24 lp / mm
* Temporal resolution		4.8 psec
* Dynamic range		390:1

This project has been supported by the Chinese National Science Foundation and the Chinese Astronomical Committee, and expected to be operational in 1994.

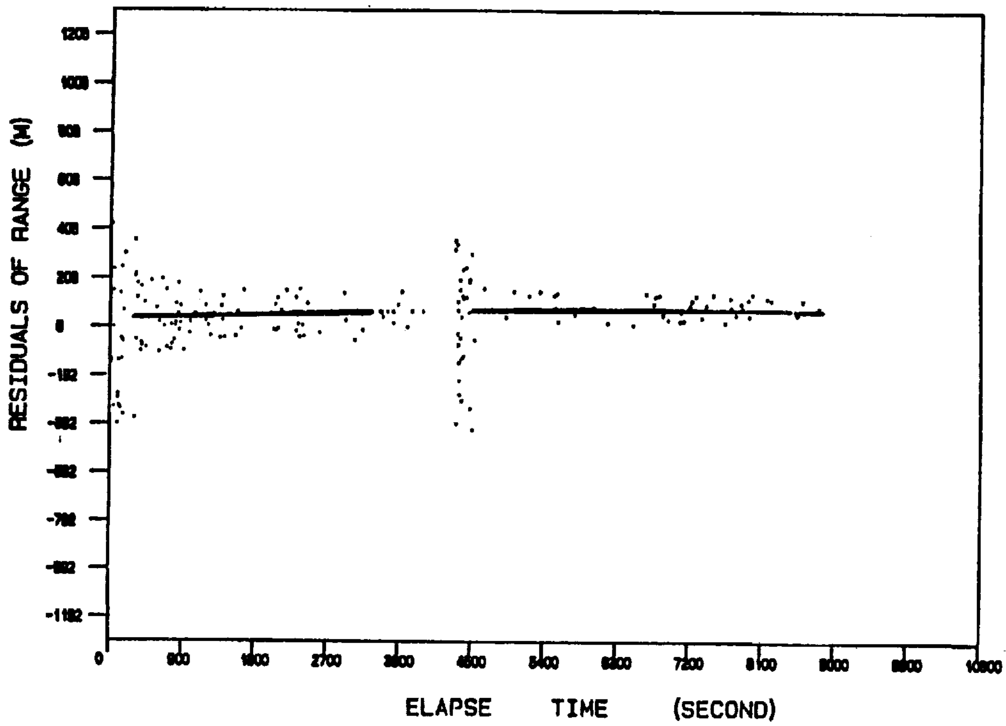

Fig. 1 One pass of Etalon-2 on August 13, 1990, 4138 Observations
Time (UTC): 11:47 Accuracy(rms): 6cm

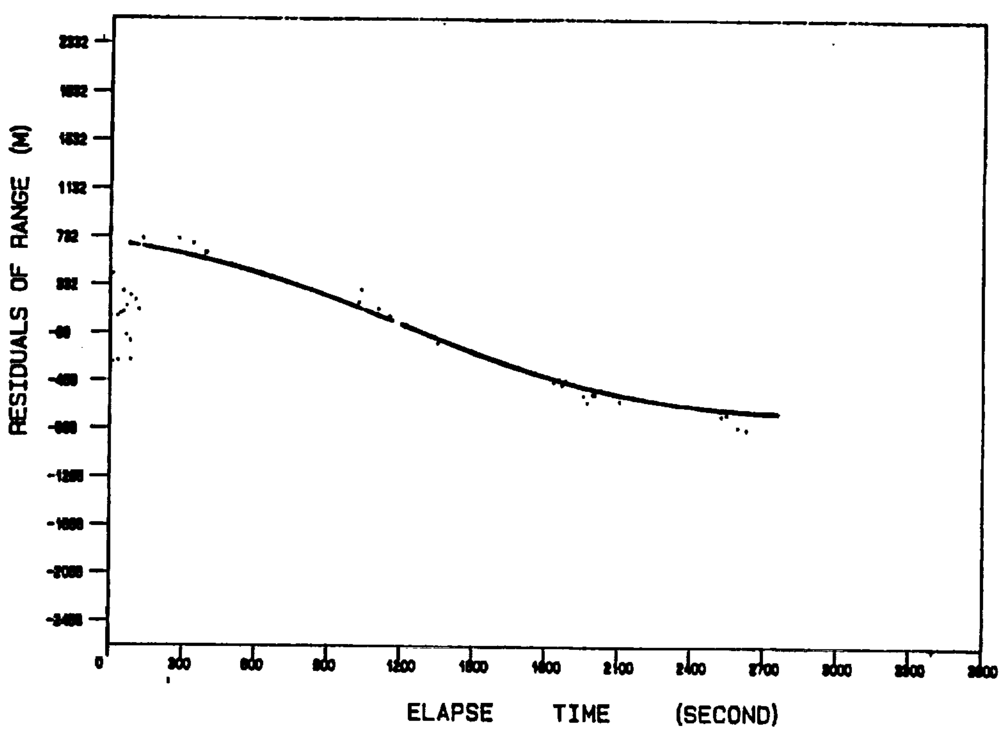

Fig. 2 One pass of Lageos on July 28, 1990, 2865 Observations
Time (UTC): 18:17 Accuracy(rms): 5cm

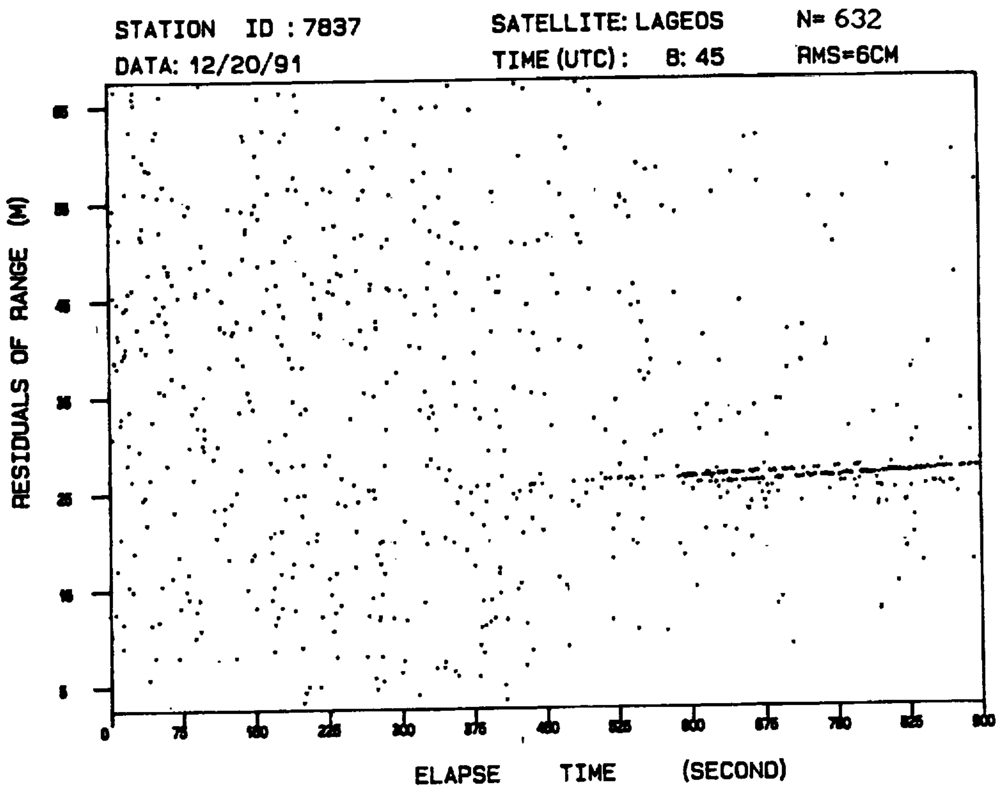

Fig. 3 Daylight tracking to Lageos on December 20, 1991

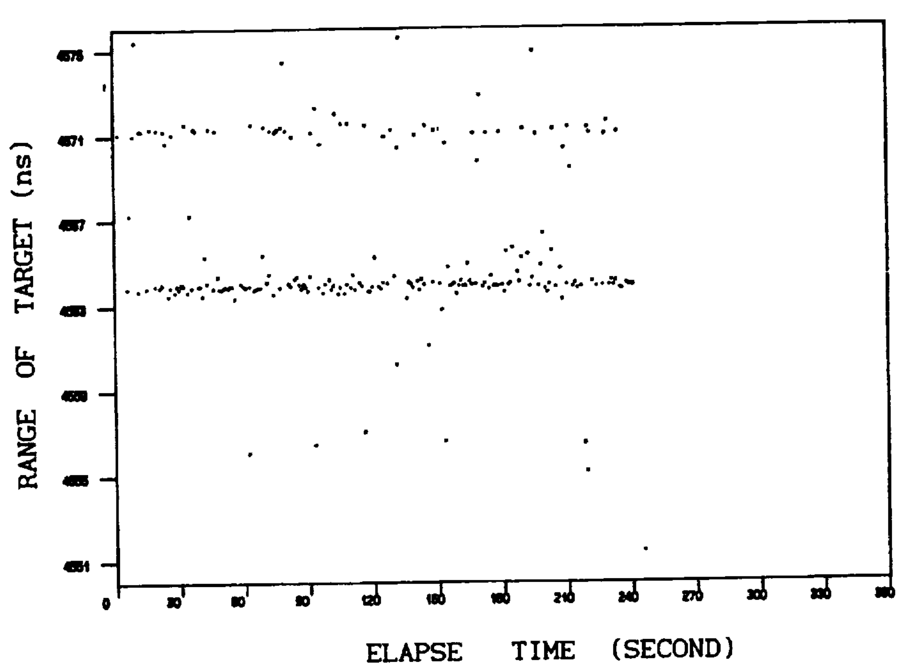

Fig. 4 Ground target calibration on May 9, 1992
with 10 psec laser train and a SPAD receiver

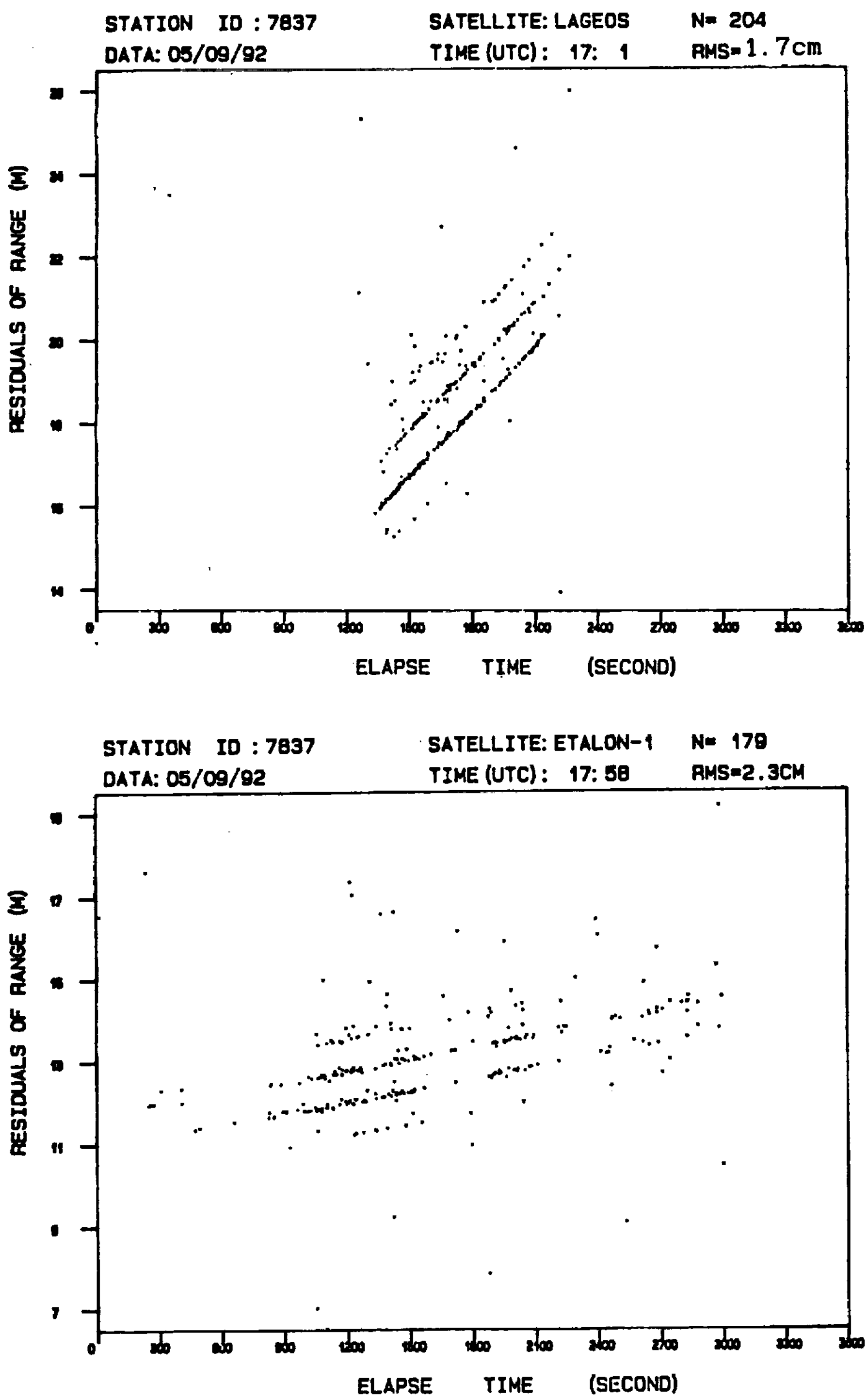

Fig.5 Results of ranging to Lageos and Etalon-1 with a 10 psec laser and a SPAD receiver (May 9, 1992) Single shot accuracy(rms): 1.7--2.3 cm